

Contract Number: W81XWH-17-P-0022
Support the (TCCCR) Task Area for Research and Development
of Medical Equipment to Clear and Maintain a Combat Airway

**A Report on Deliverable Five:
Evaluate Current Commercially Available Suction
Pump Devices for Use in Prehospital Combat Care**

Report Authors:
Priya Jain, BS¹
R. Lyle Hood, PhD²
Robert A. De Lorenzo, MD, MSCI, MSM, FACEP³

¹Department of Biomedical Engineering, University of Texas at San Antonio

²Department of Mechanical Engineering, University of Texas at San Antonio

³Department of Emergency Medicine, UT Health San Antonio

20 September 2017

Table of Contents

Objective of the Report.....	3
Background	3
<i>Summary of the Background Section.....</i>	<i>4</i>
<i>Recommendations of Background Section.....</i>	<i>4</i>
Military Requirements for Suction Devices	4
<i>Summary of the Military Requirements for Suction Devices Section.....</i>	<i>5</i>
<i>Recommendations of the Military Requirements for Suction Devices Section.....</i>	<i>5</i>
Overview of Currently Available Suction Pump Devices.....	6
<i>Compilation of Suction Pump Devices.....</i>	<i>6</i>
<i>Summary of the Overview of Currently Available Suction Pump Devices</i>	<i>23</i>
<i>Recommendations of the Overview of Currently Available Suction Pump Devices</i>	<i>23</i>
Summary and Conclusions.....	23
Acknowledgements.....	25
Appendix A - Section Summaries and Recommendations.....	26
Appendix B - Key Task of the Report.....	28
Appendix C - Technical Approach	29
Appendix D – Consumer Style Comparison Table of Suction Pump Devices.....	31
Appendix E – Web Links for Images	34
References	37

Objective of the Report

Develop a consumer-style report for currently available suction pump devices on the market. List parameters such as suction flow rate, pressure, dimensions, weight, and battery life. Suction devices for prehospital combat casualty care have unique performance requirements, and this report will evaluate whether suction devices that are currently on the market meet these requirements.

Background

[Readers are referred to the following for a more detailed overview and background on portable suction for use in prehospital combat casualty care: *A Report on Deliverable One: Determine Required Performance Characteristics [of Suction] for Management Of Prehospital Combat Casualty Care Injuries*. Contract Number: W81XWH-17-P-0022 Support the (TCCCR) Task Area for Research and Development of Medical Equipment to Clear and Maintain a Combat Airway. Report Author: Robert A. De Lorenzo, MD, MSCI, MSM, FACEP, Department of Emergency Medicine, UT Health San Antonio, February 22, 2017.]

Tactical airway management often determines survival in both trauma and medical patients. Skilled interventions often make the critical difference in survival for patients with actual or impending airway compromise. Managing airways in the tactical environment presents an additional level of unique and complex challenges for any emergency provider. Hazardous or confined spaces and hostile action inherently limit the ability to intervene with an artificial airway or assisted ventilation. Loss of patient airway in tactical and combat environments commonly occurs. The proximate cause can be direct trauma to the airway structures or indirectly from traumatic shock or brain injury and the subsequent loss of airway protective reflexes.

There is limited information on the types, if any, of portable suction units carried by combat medics in the far-forward combat area. Anecdotal information suggests that powered suction devices are simply too heavy to be carried in the combat medic's aid kit. Manual powered devices, while lightweight, offer limited capability and require the use of a hand or foot to operate, limiting efficiency of the provider. Fielding data from military logistics agencies on the number and types of suction units employed in the field is not available, and prior experience suggests even if obtained, the data shows only total purchases and not where and when fielded.

Existing portable suction standards are civilian-oriented, lack a detailed base of evidentiary support, and in any case do not satisfy the critical needs of combat casualty

care. Importantly, there are few suction units specifically built for use in this setting. We will review the available literature and guidelines on current commercially available suction devices

Summary of the Background Section

- There are few suction devices specifically built for use in prehospital combat casualty care .
- This report will focus on current commercially available suction devices, highlighting important aspects of each device including weight, dimensions, flow rate, vacuum pressure, and battery life.
- Operator safety (i.e., the risk of blood or body fluid exposure) will not be addressed in this report.

Recommendations of Background Section

- None specified.

Military Requirements for Suction Devices

There are no set military standards for medical suction devices. Tactical Combat Casualty Care (TCCC) guidelines are updated annually, which means military requirements are changing regularly. There are also different medical personnel with various needs, which render it difficult to standardize requirements. For example, medics working in the front-line will require a lightweight, compact suction device design that is easy to carry. Medics working from ambulances can carry heavier or larger equipment, and also have more options for power supply. Because of these different needs, there is no single standard or list of specifications that can be recommended. Any currently listed specifications should remain flexible to the various combat medic roles and changing TCCC guidelines. With these in mind, there are some important performance measures that should be taken into account including weight, dimensions, portability, sterilization, air flow and vacuum pressure, collection canister volume, and whether the pump is battery operated.

Combat situations can be stressful with many confounding mission, field, and environmental variables such as extreme temperatures, different tactical situations, difficult terrains, and combat search and rescue (CSAR) operations. Airway suction device performance under various environmental parameters should be assessed, such

as altitude, vibration, temperature, and humidity. Furthermore, device suction should be assessed when the device itself is wet or in a strong electric field. In high casualty scenarios, a suction device that can be operated without any prior medical training is highly preferred¹. Because of these variables, there are several military requirements for airway suction devices to be suitable for field use. Due to the diverse terrains and tactical situations, the device must be durable, easy to transport, and easy to sterilize². Tubing for the suction device must be clear to allow for constant monitoring of the suction process and any clogging of the device. Large-bore tubing is preferred to smaller tubing, as the latter can only be used to suction low viscosity fluids with little to no debris³. Similar suction efficacy should be available to combat medics as in civilian clinical settings⁴, which eliminates the use of manual, unpowered suction devices. Manually-powered suction devices do not provide as much flow rate their electrical-driven counterparts, although they may be more lightweight and portable. In addition, combat-ready suction devices must differ from their civilian counterparts by being compact, rugged, and quiet (reduced Infra-red (IR)/noise signatures)⁴. The maximum weight for a military suction device should ideally be as light as possible; a realistic weight for a battery-operated, rugged device is a kilogram or less. Because of cross-contamination issues on the field, it may be easier to have disposable as many components that potentially contact patient blood and body fluids. This includes at a minimum the tubing and collection chambers.

Summary of the Military Requirements for Suction Devices Section

- There are no set military standards for suction units; however, there are important performance standards that need to be maintained when manufacturing a device, including weight, dimensions, portability, sterilization, air flow and vacuum pressure, collection canister volume, and whether the pump is battery operated.
- Suction devices must be built for use on different terrains and extreme weather situations. They should be rugged with an extended battery life that is easy to change without the need of a power supply for recharge.

Recommendations of the Military Requirements for Suction Devices Section

- Standards should be established relevant to universal use for military personnel with different needs. Some important design concepts to consider are:
 - Size, weight, and ergonomics
 - Vacuum pressure similar to that in clinical use
 - Battery operated and easily replaceable batteries
 - Rugged and operable in all orientations

- Extreme weather conditions

Overview of Currently Available Suction Pump Devices

There are currently several suction pump devices available for use. Many of these devices are used in hospital settings or ambulances; however, their use in combat situations is not feasible due to a variety of limitations including, but not limited to, limited operating temperatures, heavy weight, bulky dimensions, or short battery life. This document consists of a compiled list of some of these devices. To see a comparison table of all devices with more performance variables such as canister size, see Appendix D. To read about the method of approach in finding these devices, see Appendix C.

Compilation of Suction Pump Devices

1. Aeros Tote-L-Vac Suction Unit



Weight	15.5 lbs
Dimensions	8 x 12 x 9.5 in
Flow Rate	36 LPM
Vacuum Pressure	Up to 550 mmHg
Battery Life	30 minutes, rechargeable

Consumer reviews were not found. The manufacturer claims that this device can provide high enough vacuum pressure and flow rates to perform airway clearance procedures despite its compact size. Due to the battery power and portability, the Tote-L-Vac could be used for EMS, home health, hospital patient transport, and wherever battery power is a requirement. Performance reviews were not available and there is no summary recommendation on the product.

2. Ambu Res-Cue Manual Suction Pump



Weight	0.507 lbs
Dimensions	7.28 x 2.52 x 6.61 in
Flow Rate	>20 LPM
Vacuum Pressure	225 to 450 mmHg
Battery Life	Hand-powered

Consumer reviews for this device were found on Amazon. Overall, the Ambu Res-Cue Manual Suction Pump received 4.0/5.0 stars. Reviewers claim this device is compact and easy to assemble. It would not be recommended for dedicated EMS use as the suction power is not guaranteed, but it is recommended for emergencies in which battery-powered devices are not available.

3. Curaplex Manual Suction Unit



Weight	0.6 lbs
Dimensions	7.09 x 8.66 x 3.15 in
Flow Rate	>20 LPM
Vacuum Pressure	450 mmHg
Battery Life	Hand-powered

Consumer reviews for this device were found on Amazon. The Curaplex Manual Suction Unit received 2.4/5.0 stars. Several reviewers claim the device they received suctioned very little, if at all, while other reviewers claim they could use this device in non-emergency settings. This product has potential but the execution could not be verified.

4. DeVilbiss 7305D Series Homecare Suction Unit



Weight	3.8 lbs
Dimensions	9 x 7 x 8 in
Flow Rate	27 LPM
Vacuum Pressure	80 to 550 mmHg
Battery Life	60 min, rechargeable

Consumer reviews for this device were found on Vitality Medical. The DeVilbiss 7305D received 3.5/5.0 stars. Every single reviewer claims this device is too loud. One reviewer stated that the noise outweighed any of the positive aspects; however, all other reviewers stated it did clear airways despite the loud noise. It follows performance standards stated in ISO 10079-1.

5. Drive Medical VacuMax Suction Machine with Rechargeable Battery



Weight	5 lbs
Dimensions	12.4 x 9.8 x 8.1 in
Flow Rate	25 LPM
Vacuum Pressure	150 to 530 mmHg
Battery Life	50 min, rechargeable

Consumer reviews for this device were found on Drive Medical. The VacuMax Suction Machine received an average of 3.5/5.0 stars from two reviewers. One reviewer claims the device is poorly designed and does not take into consideration ease of use for wheelchair patients. Both reviewers stated the device has good suction ability and works well.

6. EM Innovations Suction Easy Pump



Weight	0.419 lbs
Dimensions	10 5/8 x 11 7/8 in
Flow Rate	Not specified
Vacuum Pressure	100 mmHg
Battery Life	Hand-powered

Only one consumer review was found on Amazon. The EM Innovations Suction Easy Pump received 3.0/5.0 stars. The reviewer claimed that the device is useful but not for ambulances and that the bulb was hard to squeeze. The manufacturer claims this device is an inexpensive solution for training purposes and is a must have in first responder airway kits because it is easy, disposable, and compact.

7. Emergency Aspirator from Vitalograph



Weight	0.882 lbs
Dimensions	6.5 x 6.5 x 3.43 in
Flow Rate	4.56 LPM
Vacuum Pressure	120 to 450 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The manufacturer claims this hand-powered device is widely used in hospital and military settings. The Emergency Aspirator conforms to EN ISO 10079-2 and is made from tough polycarbonate to withstand serious shocks. It is also easy to disassemble for cleaning and has a unique overflow design. Performance reviews were not available and there is no summary recommendation on the product.

8. Eurovac AC Suction Unit



Weight	17.6 lbs
Dimensions	16.9 x 8.66 x 14.6 in
Flow Rate	45 LPM
Vacuum Pressure	575 mmHg
Battery Life	110 V on request

Consumer reviews were not found. The manufacturer claims that this device has low maintenance costs and has built in mechanical overflow safety as well as an electronic acoustic alarm. The Eurovac is used on hospital crash carts, during patient transfers, long-term home care, by tracheostomy, and by EMS. Performance reviews were not available and there is no summary recommendation on the product.

9. EuroLite Suction Device



Weight	9.92 lbs
Dimensions	11.8 x 5.51 x 13 in
Flow Rate	12 LPM
Vacuum Pressure	600 mmHg
Battery Life	110 V on request

Consumer reviews were not found. The manufacturer claims that this device has low maintenance costs and has built in mechanical overflow safety as well as an electronic acoustic alarm. The EuroLite is used in nursing, obstetrics, and neonatal and pediatrics. Performance reviews were not available and there is no summary recommendation on the product.

10. Gomco OptiVac AC/DC Portable Aspirator Model G180



Weight	11.4 lbs
Dimensions	16.8 x 7.5 x 9.4 in
Flow Rate	>30 LPM
Vacuum Pressure	25 to 550 mmHg
Battery Life	3 hours, rechargeable

Only one consumer review was found for this product in which the reviewer states that the Gomco OptiVac G180 is portable and dependable. The manufacturer claims this device can operate for 3 hours when fully charged and has a rugged go-anywhere design. It was tested to UL 60601-1 standards. Performance could not be verified, as there are no relevant reviews available.

11. INSTAD Suction Pump



Weight	8.82 lbs
Dimensions	15.4 x 8.7 x 8.7 in
Flow Rate	25 LPM
Vacuum Pressure	700 mmHg
Battery Life	110 V on request

Consumer reviews were not found. The manufacturer claims that this device has low maintenance costs and has built in mechanical overflow safety. The INSTAD is used on hospital crash carts, during patient transfers, long-term home care, by tracheostomy, and by EMS. Performance reviews were not available and there is no summary recommendation on the product.

12. John Bunn Vacutec 800 EV2 Portable Aspirator Suction Unit



Weight	11.6 lbs
Dimensions	4.9 x 15.3 x 10 in
Flow Rate	0 to 40 LPM
Vacuum Pressure	0 to 560 mmHg
Battery Life	115 VAC

Consumer reviews were found on 4MD Medical. The John Bunn Vacutec 800 EV2 received 5.0/5.0 stars from 8 reviewers. All reviewers claim this product does exactly what it advertises. One reviewer stated that it is dependable and may be a good option for field medical or dental applications. It complies with EN60601 standards.

13. Laerdal Compact Suction Unit LCSU 4 (300 mL) RTCA Certificate



Weight	3.375 lbs
Dimensions	7.3 x 10.3 x 3.2 in
Flow Rate	30 LPM
Vacuum Pressure	50 to 550 mmHg
Battery Life	45 min, no-tools-necessary field changeable

Consumer reviews were not found. The manufacturer claims this product has a rugged and lightweight design that exceeds international performance standards, which makes it an essential tool for first responders. It also has an overflow shutoff feature for the canister. This product is certified for use in aircrafts. Performance reviews were not available and there is no summary recommendation on the product.

14. Laerdal Suction Unit



Weight	8.9 lbs
Dimensions	12.4 x 13 x 6.3 in
Flow Rate	>30 LPM
Vacuum Pressure	80 to 500 mmHg
Battery Life	45 minutes, no-tools-necessary field changeable

Consumer reviews were not found. The manufacturer claims the Laerdal Suction Unit is effective at improving patient safety because it is powerful and effective and exceeds international standards. This product is in compliance with the Council Directive 93/42/EEC Medical Device Directive. Performance reviews were not available and there is no summary recommendation on the product.

15. Laerdal V-Vac Starter Kit



Weight	0.644 lbs
Dimensions	13.5 x 2.5 x 4.8 in
Flow Rate	70 LPM
Vacuum Pressure	170 to 380 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The manufacturer claims the disposable suction tip is built to prevent tube occlusions. The handle for this device is reusable and can be cleaned with warm, soapy water between uses. This product is in compliance with the Council Directive 93/42/EEC. Performance reviews were not available and there is no summary recommendation on the product.

16. LSP Advantage Emergency Portable Suction Unit



Weight	10.6 lbs
Dimensions	16.8 x 9.4 x 7.5 in
Flow Rate	30 LPM
Vacuum Pressure	25 to 550 mmHg
Battery Life	75 min, rechargeable

Consumer reviews were not found. The manufacturer claims this product is built to be used in the field, ambulances, and helicopters. The LSP Advantage Emergency Portable Suction Unit will operate at full power when plugged in and for 75 minutes when fully charged. This product also claims to have a versatile vacuum range, from 25 to 550 mmHg. Performance reviews were not available and there is no summary recommendation on the product.

17. Medela Basic Aspirator



Weight	20.5 lbs
Dimensions	8.3 x 12 x 14.8 in
Flow Rate	30 LPM
Vacuum Pressure	675 mmHg
Battery Life	US AC plug

Consumer reviews were not found. The manufacturer claims the Medela Basic Aspirator is built to perform in hospitals, clinics, and medical practices. It cannot operate unless plugged in. Performance reviews were not available and there is no summary recommendation on the product.

18. Medela Dominant Flex Aspirator



Weight	20.5 lbs
Dimensions	8.3 x 12 x 14.8 in
Flow Rate	40 to 60 LPM
Vacuum Pressure	713 mmHg
Battery Life	Plug into wall

Consumer reviews were not found. The manufacturer claims the Medela Basic Aspirator is built to perform in hospitals, clinics, and medical practices. It cannot operate unless plugged in. Performance reviews were not available and there is no summary recommendation on the product.

19. Medline Vac-Assist Portable Aspirator Suction Machine



Weight	12.1 lbs
Dimensions	14.8 x 9.8 x 6.8 in
Flow Rate	>40 LPM
Vacuum Pressure	0 to 560 mmHg
Battery Life	AC 115 VAC

Consumer reviews were not found. The manufacturer claims the Medline Vac-Assist has a rugged design for frequent use and is designed for home or hospital use. This product can handle oral, nasal, and tracheal suction. It has a quiet motor, at only 58 dB, and is easy to clean. Performance reviews were not available and there is no summary recommendation on the product.

20. MedSource Manual Suction Pump



Weight	1 lb
Dimensions	8.8 x 7.1 x 3.2 in
Flow Rate	>20 LPM
Vacuum Pressure	450 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The manufacturer claims the Medsource Manual Suction Pump can be powered using only one hand. It is simple to operate during emergency situations. The pump is reusable while the canister and tubing are disposable and meant for single use. Performance reviews were not available and there is no summary recommendation on the product.

21. Morgan Suction Pump



Weight	1 lb
Dimensions	3.15 x 2.75 x 1.4 in
Flow Rate	>20 LPM
Vacuum Pressure	550 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The manufacturer states that the Morgan Suction Pump is an FDA registered class 1 medical suction kit. This product should be able to prevent back-flow and is completely disposable. It was designed for use by hospice field nurses. Performance reviews were not available and there is no summary recommendation on the product.

22. North American Rescue (NAR) Tactical Suction Device



Weight	0.46 lbs
Dimensions	9.75 x 3.75 x 3 in
Flow Rate	Not specified
Vacuum Pressure	100 mmHg
Battery Life	Hand-powered

Two consumer reviews were found on Rescue Essentials. The NAR Tactical Suction Device is said to be highly effective, especially for EMS and military medical settings. One reviewer claims this is the only manual suction product that works. The manufacturer claims this device can be used with one hand.

23. Portable Vacuum Absorb Pump Phlegm Suction Unit Suction Machine SXT-5A



Weight	8.82 lbs
Dimensions	16.1 x 8.1 x 16.5 in
Flow Rate	>20 LPM
Vacuum Pressure	150 to 600 mmHg
Battery Life	110 VAC

Consumer reviews were not found. The manufacturer claims that the SXT-5A is used for treatment in hospitals, first aid stations, or centers of social medical service. It is designed to aspirate highly viscous secretions such as mucus and phlegm from infants to adults. This product has overflow protection and is autoclavable. Performance reviews were not available and there is no summary recommendation on the product.

24. Precision Medical PM66AC EasyGoVac Portable Aspirator Suction Machine



Weight	3.25 lbs
Dimensions	8.6 x 6.3 x 8.02 in
Flow Rate	>20 LPM
Vacuum Pressure	51 to 533 mmHg
Battery Life	2 hours, rechargeable

Consumer reviews were not found. The manufacturer claims that lithium batteries provide fast 2 hour recharge. The PM66AC EasyGoVac can come with either a disposable 800 mL canister or a reusable 1200 mL canister. Performance reviews were not available and there is no summary recommendation on the product.

25. Res-Q-Vac



Weight	0.5 lbs
Dimensions	4.49 x 7.1 x 2.15 in
Flow Rate	20 LPM
Vacuum Pressure	>600 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The Res-Q-Vac is built for EMS operators and technicians, hospitals, nursing homes, home care, and the military. The manufacturers claim that this product can be customizable for use with infants through adults. This product is made with molded ABS plastic, which is rugged and durable. This product can only operate in temperatures that range from 0 to 140 °F. Performance reviews were not available and there is no summary recommendation on the product.

26. Roscoe Medical Heavy-Duty Aspirator Suction Machine



Weight	5.7 lbs
Dimensions	14.3 x 6.9 x 8.3 in
Flow Rate	28 LPM
Vacuum Pressure	550 mmHg
Battery Life	30 minutes, rechargeable

Consumer reviews were not found. The manufacturer claims this product is easy to handle and transportable due to its light weight. It has built-in overflow protection and is easy to clean. This product also claims to have an anti-vibration vacuum gauge setting. Performance reviews were not available and there is no summary recommendation on the product.

27. SAM E.P.S. Portable Suction Unit



Weight	10.4 lbs
Dimensions	13.7 x 13 x 6.65 in
Flow Rate	32 LPM
Vacuum Pressure	0 to 600 mmHg
Battery Life	125 min full power, rechargeable

Consumer reviews were not found. The manufacturer claims that this device is ideal for use by emergency services because it is lightweight and can be recharged within 2.5 hours. This product also has a 90° rotating canister vessel, which allows the device to be laid flat even on uneven terrain. Due to its BioCloak coating, it is ideal for outside use. Performance reviews were not available and there is no summary recommendation on the product.

28. SSCOR QUICKDRAW Alkaline Powered Portable Suction, Olive Drab

Weight	2.6 lbs
Dimensions	10.5 x 4.5 x 4.35 in
Flow Rate	>30 LPM
Vacuum Pressure	80 to 500 mmHg
Battery Life	Up to 3 hours, 10 AAA batteries

Consumer reviews were not found. This product was designed specifically for field use, which can be seen due to its light weight and changeable AAA batteries. The manufacturer claims that alkaline batteries have a long shelf life, which means this product does not require constant charging and can be stored in aid bags with minimal degradation. It is not specified the range of temperatures the Olive Drab Quickdraw can operate in. This product conforms to ISO 10079-1, UL 60601-1, IEC 60601-1, EN 60601-1-2 standards. Performance reviews were not available and there is no summary recommendation on the product.

29. SSCOR VX-2

Weight	8.6 lbs
Dimensions	17 x 9 x 5.25 in
Flow Rate	>30 LPM
Vacuum Pressure	50 to 525 mmHg
Battery Life	45 min, rechargeable

Consumer reviews were not found. The manufacturer claims this device is “Firefighter” tough, portable, and powerful. It meets state, national, and international standards for portable suction equipment. This product has a built-in battery maintenance system to prevent overcharges and deep discharges of the battery. It is compliant with SAE J3043 standards. Performance reviews were not available and there is no summary recommendation on the product.

30. S-SCORT 9 Suction



Weight	8 lbs
Dimensions	9.5 x 7 x 14 in
Flow Rate	>30 LPM
Vacuum Pressure	120 or 525 mmHg
Battery Life	30-45 min, rechargeable

Consumer reviews were not found. The manufacturer claims this product is quiet and is “Firefighter-proof” tough, being the most durable, economic, and high-performance suction pump available. It is suited for pre-hospital healthcare environments due to its durability and ease of cleaning. Performance reviews were not available and there is no summary recommendation on the product.

31. S-SCORT II Portable Suction Unit



Weight	10 lbs
Dimensions	7 x 7 x 14 in
Flow Rate	>30 LPM
Vacuum Pressure	120 or 525 mmHg
Battery Life	20 min on each battery, supplied by user

Consumer reviews were not found. This product is designed to fit LifePak 5, 10, and 12 defibrillators and is not rechargeable. The manufacturer claims the device is covered by vinyl coated nylon for easy wipe down and disinfection. Performance reviews were not available and there is no summary recommendation on the product.

32. S-SCORT III Portable Suction Unit

Weight	7 lbs
Dimensions	8 x 7 x 11 in
Flow Rate	>30 LPM
Vacuum Pressure	120 or 525 mmHg
Battery Life	30 to 45 min, rechargeable

Consumer reviews were not found. The manufacturer claims this product is durable, reliable, and an economical EMS suction device. It provides power and versatility while being relatively light weight. Performance reviews were not available and there is no summary recommendation on the product.

33. S-SCORT Ten

Weight	10 lbs
Dimensions	9.5 x 7 x 14 in
Flow Rate	>30 LPM
Vacuum Pressure	120 or 525 mmHg
Battery Life	45 min, rechargeable

Consumer reviews were not found. The manufacturer claims the linear polyethylene rotational molded exterior of the S-SCORT Ten makes it virtually indestructible. The power can be adjusted in this device between full power and lower vacuum settings for pediatric aspiration. It also has a built-in battery maintenance system to automatically disconnect the battery when the battery is depleted in order to avoid deep discharge. Performance reviews were not available and there is no summary recommendation on the product.

34. Vacu-Aide Portable Compact Suction Unit



Weight	3.37 lbs
Dimensions	7.25 x 7.25 x 6.75 in
Flow Rate	27 LPM
Vacuum Pressure	50 to 500 mmHg
Battery Life	Up to 60 min, rechargeable

Consumer reviews were not found. The manufacturer claims the Vacu-Aide is the smallest and strongest suction unit of its kind. This product is ideal for home and hospital use. It complies with ISO 10079-1 standards. Performance reviews were not available and there is no summary recommendation on the product.

Summary of the Overview of Currently Available Suction Pump Devices

- There are a variety of suction pump devices on the market; however, very few of them claim to be useful for combat casualty care.
- This list is an overview of different types of suction pump devices that can be found through a web-based search for portable devices.

Recommendations of the Overview of Currently Available Suction Pump Devices

- There are few suction pump devices that state they can be used for prehospital combat use.
- Suction devices that do claim a prehospital combat use require independent validation and need to be adjusted for operability in a wider range of conditions with smaller dimensions and lighter weights.

Summary and Conclusions

Airway suction is a critical component of airway management, which is the second leading cause of preventable battlefield death. There are several commercially available suction pump devices for use in various settings; however, few of them are compliant with aspiration needs for combat casualty use. Suction devices for military use must

perform under a variety of extreme conditions, such as altitude, vibration, temperature, humidity, wetness, etc. The list of devices presented here in a consumer style report provides an overview of the different types of available products.

Acknowledgements

The authors wish to acknowledge the administrative and editorial skill, tireless effort and patience of Heather Wantuch, MPA; and the technical advice, support and background information of Bruce Adams, MD and Yusheng Feng, PhD.

Appendix A - Section Summaries and Recommendations

Summary of the Background Section

- There are few suction devices specifically built for use in prehospital combat casualty care .
- This report will focus on current commercially available suction devices, highlighting important aspects of each device including weight, dimensions, flow rate, vacuum pressure, and battery life.
- Operator safety (i.e., the risk of blood or body fluid exposure) will not be addressed in this report.

Recommendations of Background Section

- None specified.

Summary of the Military Requirements for Suction Devices Section

- There are no set military standards for suction units; however, there are important performance standards that need to be maintained when manufacturing a device, including weight, dimensions, portability, sterilization, air flow and vacuum pressure, collection canister volume, and whether the pump is battery operated.
- Suction devices must be built for use on different terrains and extreme weather situations. They should be rugged with an extended battery life that is easy to change without the need of a power supply for recharge.

Recommendations of the Military Requirements for Suction Devices Section

- Standards should be established relevant to universal use for military personnel with different needs. Some important design concepts to consider are:
 - Size, weight, and ergonomics
 - Vacuum pressure similar to that in clinical use
 - Battery operated and easily replaceable batteries
 - Rugged and operable in all orientations
 - Extreme weather conditions

Summary of the Overview of Currently Available Suction Pump Devices

- There are a variety of suction pump devices on the market; however, very few of them claim to be useful for combat casualty care.
- This list is an overview of different types of suction pump devices that can be found through a web-based search for portable devices.

Recommendations of the Overview of Currently Available Suction Pump Devices

- There are few suction pump devices that state they can be used for prehospital combat use.
- Suction devices that do claim a prehospital combat use require independent validation and need to be adjusted for operability in a wider range of conditions with smaller dimensions and lighter weights.

Appendix B - Key Task of the Report

Evaluate current commercially available products against operational requirements and ergonomic factors. This evaluation will be a design specification evaluation comparing the manufacturer's published specifications. Deliverables will be 1) a report comparing commercially available devices.

Appendix C - Technical Approach

General Approach:

Existing and projected (future) military medical requirements relevant to the expected combat and operational scenarios (such as prolonged field care) are identified. The required performance characteristics of a suction unit intended for prehospital combat casualty care is ascertained based on these anticipated operational scenarios. The key characteristics searched include vacuum suction flow rate, pressure, and capacity to evacuate the expected fluid/particle viscosity/size (e.g., saliva, blood, vomitus, mud, gravel, broken teeth) for management of prehospital Combat Casualty Care injuries. Source documents were extracted from 1980-present and analyzed for title content. If relevant, the article was reviewed in detail. Secondary references prior to 1980 were selectively searched based on the title and the likelihood of topical relevance. Specific sources searched include but are not limited to:

- Committee on Combat Casualty Care (CoTCCC)
- Medical literature using Medline or equivalent with search terms including
 - *Suction*
 - *Vacuum*
 - *Aspiration*
 - *Airway, airway management*
 - *Airway obstruction*
 - Modifier terms including *safety, efficacy, and performance*
- Engineering literature using Academic Search (EBSCO), or equivalent using similar search terms as above
- Defense Technical Information Center (DTIC)
- Retrievable information from conferences and meetings focused on combat casualty care, prehospital care, and airway management.
- Government standards including FDA
- Industry and government standards clearinghouses including ISO

Where necessary to fill in information gaps, existing requirements were supplemented with proposed requirements vetted against local expert military and civilian medical consultations. UT Health San Antonio maintains a robust panel of US military experts in

emergency medicine and prehospital care that can be consulted. Additionally, UT Health San Antonio is in close proximity to and maintains a healthy relationship with JBSA-Fort Sam Houston which is the US military's key hub of combat casualty care and trauma training, and UT Health San Antonio retains the ability to consult with the organizations and personnel within this installation as well as other US military installations worldwide.

The available information is organized, critically appraised, and synthesized into a narrative report that summarizes the current commercially available suction pump devices.

Specific Approach:

Study Aim: The primary goal of this study is to explore current commercially available suction pump devices and provide a consumer style report based on those devices.

Key Words of Search: Suction; Vacuum; Airway; Consumer; Report; Manufacturer; Performance Test; Obstruction; Intubation.

OBJECTIVE: Research and review current commercially available suction pump devices and create a consumer style report in a comparison table as well as listed by product.

METHODS

An internet search was conducted to find current commercially available suction pump devices of various styles and uses. There are currently no suction devices specifically designed for military use. A consumer style report was developed to compare the various devices and provide an overview of performance variables for each device. This report was aimed at portable suction pump devices due to the focus being on devices designed for military use. The important performance guidelines to analyze were battery life, weight, dimensions, flow rate, vacuum pressure, canister capacity, price, and number of uses. The consumer style comparison table was then filled in for each device found and can be found in Appendix D. A summary of each device with a table of performance guidelines was written based on reviewer comments or claims made on the manufacturer websites.

Appendix D – Consumer Style Comparison Table of Suction Pump Devices

Suction Device Name	Weight	Dimensions	Flow Rate	Vacuum Pressure	Canister capacity	Price, \$	One time use?	Extra information	Website
Aeros Tote-L-Vac Suction Unit	15.5 lbs	8 x 12 x 9.5 in	36 LPM	up to 550 mmHg	800 cc	599.99	Disposable waste container, tubing, suction tip		https://www.ohiomedical.com/literature/550150%20toteLvac%20Rev10.pdf
Ambu Res-Cue Manual Suction Pump	0.507 lbs	7.28 x 2.52 x 6.61 in	>20 LPM	225 to 450 mmHg	300 mL	61.37	Disposable waste container	overflow protection	http://www.ambu.com/corp/products/emergency_care/product/res-cue_pump-prod875.aspx
Curaplex Manual Suction Unit	0.6 lbs	7.09 x 8.66 x 3.15 in	>20 LPM	450 mmHg	300 ml	61.99	Disposable waste container	Similar to the Laerdal V-Vac & Ambu Res-Que Pump	http://www.liveactionsafety.com/curaplex-manual-suction-unit/?gclid=CjwKEAjwytLKBRCX547gve7EsE4SJAD3IZV6y1LB5iYa2Qg4WQyZCOrRi8NAZGXhCP5Tj3sEGusrxBoCcLrw_wcB
DeVilbiss 7305D Series Homecare Suction Unit	3.8 lbs	9 x 7 x 8 in	27 LPM	80-550 mmHg	800 or 1200 mL	467.99	800 ml canister disposable, 1200 ml reusable	tested to ISO 10079-1: 1999 standards	http://www.devilbisshealthcare.com/products/suction-therapy/homecare-suction-unit
Drive Medical VacuMax Suction Machine with Rechargeable Battery	5 lbs	12.4 x 9.8 x 8.1 in	25 LPM	150-530 mmHg	800 cc	408.06	No, clean with warm water; filter needs to be replaced if it gets wet		http://cdn.drivemedical.com/media/files/1701/18610_18615_Manual_V4_4_30.pdf
EM Innovations Suction Easy Pump	0.419 lbs	10 5/8 x 11 7/8 in	not specified	100 mmHg	>1000 cc	35.22	yes		http://www.eminnovations.com/assets/images/Suction%20Easy%20Technical%20Bulletin.pdf
Emergency Aspirator from Vitalograph	0.882 lbs	6.5 x 6.5 x 3.43 in	4.56 LPM	120-450 mmHg	240 ml	199.24	no, clean with cold liquid, ResusBag can be single-use	follows performance standards ISO 10079-2	https://vitalograph.co.uk/product/162440/aspirator
Eurovac AC Suction Unit	17.6 lbs	16.9 x 8.66 x 14.6 in	45 LPM	575 mmHg	1 x 2 L	197.00	no, autoclave		http://www.narang.com/suction-machines-units/portable-suction-units/SU03a.php
EuroLite Suction Device	9.92 lbs	11.8 x 5.51 x 13 in	12 LPM	600 mmHg	1 x 1 L	114.45	no, autoclave		http://www.aticommedical.com/suction-unit.html
Gomco OptiVac AC/DC Portable Aspirator Model G180	11.4 lbs	16.8 x 7.5 x 9.4 in	>30 LPM	25-550 mmHg	1500 mL	692.00	disposable tubing, waste canister, and hydrophobic bacteria filters	tested to UL 60601-1	http://www.alliedhpi.com/images/z21-00-0001.pdf
INSTAD Suction Pump	8.82 lbs	15.4 x 8.7 x 8.7 in	25 LPM	700 mmHg	1 x 1 L	203.20	no, autoclave	mechanical overflow safety	http://www.narang.com/suction-machines-units/portable-suction-units/SU47c.php

Evaluation of Commercial Suction Devices for Prehospital Combat Casualty Care

Suction Device Name	Weight	Dimensions	Flow Rate	Vacuum Pressure	Canister capacity	Price, \$	One time use?	Extra information	Website
John Bunn Vacutec 800 EV2 Portable Aspirator Suction Unit	11.6 lbs	4.9 x 15.3 x 10 in	0-40 LPM	0-560 mmHg	800 cc	139.00	disposable waste canister	complies with EN60601 standards, automatic shut off	https://www.ventureresp.com/productcart/pc/John-Bunn-Vacutec-800-EV2-Portable-Aspirator-Suction-Unit-JB0112-016-p3175.htm
Laerdal Compact Suction Unit LCSU 4 (300 mL) RTCA Certified	3.375 lbs	7.3 x 10.3 x 3.2 in	30 LPM	50 to 550 mmHg	300 mL	590.00	disposable waste canister	certified for use in aircraft	http://www.laerdal.com/us/products/medical-devices/airway-management/laerdal-compact-suction-unit-lcsu-4/
Laerdal Suction Unit	8.9 lbs	12.4 x 13 x 6.3 in	>30 LPM	80-500 mmHg	1000 and 1200 mL	995.00	disposable waste canister and tubing		http://www.laerdal.com/us/products/medical-devices/airway-management/laerdal-suction-unit-lsu/
Laerdal V-Vac Starter Kit	0.644 lbs	13.5 x 2.5 x 4.8 in	70 LPM	170-380 mmHg	425 ml	125.00	Everything except handle		http://www.laerdal.com/us/products/medical-devices/airway-management/v-vac-manual-suction-unit/
LSP Advantage Emergency Portable Suction Unit	10.6 lbs	16.8 x 9.4 x 7.5 in	30 LPM	25-550 mmHg	800 cc	1,095.00	disposable tubing, waste canister, and hydrophobic bacteria filters	designed for use by emergency medical personnel in the field, within ambulances, and helicopters	http://www.alliedhpi.com/images/z90-00-0005.pdf
Medela Basic Aspirator	20.5 lbs	8.3 x 12 x 14.8 in	30 LPM	675 mmHg	5000 cc	2,626.50	no, sterilize		http://www.medela-healthcare.us/healthcare/products/surgical-suction/basic
Medela Dominant Flex Aspirator	20.5 lbs	8.3 x 12 x 14.8 in	40 to 60 LPM	713 mmHg	1000 to 5000 L	3,146.65	no, sterilize		http://www.medela-healthcare.us/healthcare/products/surgical-suction/dominant-flex
Medline Vac-Assist Portable Aspirator Suction Machine	12.1 lbs	14.8 x 9.8 x 6.8 in	>40 LPM	0-560 mmHg	800 ml	239.95	disposable waste canister		https://www.medline.com/product/Vac-Assist-Suction-Aspirator/Aspirators/Z05-PF01963#mrkSpec
MedSource Manual Suction Pump	1 lb	8.8 x 7.1 x 3.2 in	>20 LPM	450 mmHg	300 ml	51.98	disposable waste canister and tubing		https://www.4mdmedical.com/catalog/product/view/id/389307/?CAWELAID=120141310000056386&utm_source=google&utm_medium=cpc&adpos=1o15&scid=scplpMSIMS-001PMP&sc_intid=MSIMS-001PMP&gclid=CjwKEAjwytLKBRCX547gve7EsE4SJAD3lZV60e83Od1mHVNijgSz2ZcVBmg4RxlU86VJ46APYS6MMRoCNenw_wcB
Morgan Suction Pump	1 lb	3.15 x 2.75 x 1.4 in	>20 LPM	550 mmHg	300 mL	40.00	disposable waste container and tubing		http://morgansuctionpump.com/product-overview/
North American Rescue (NAR) Tactical Suction Device	0.46 lbs	9.75 x 3.75 x 3 in	not specified	100 mmHg	>1000 mL	37.99	yes		https://www.narescue.com/nar-tactical-suction-device
Portable Vacuum Absorb Pump Phlegm Suction Unit Suction Machine SXT-5A	8.82 lbs	16.1 x 8.1 x 16.5 in	>20 LPM	150-600 mmHg	1000 mL	224.00	no, autoclave		https://lifescienceequipment.science/phlegm-suction-unit-vacuum-absorb-pump-sxt-5a-new-potable-v-332187562446.html

Evaluation of Commercial Suction Devices for Prehospital Combat Casualty Care

Suction Device Name	Weight	Dimensions	Flow Rate	Vacuum Pressure	Canister capacity	Price, \$	One time use?	Extra information	Website
Precision Medical PM66AC EasyGoVac Portable Aspirator Suction Machine	3.25 lbs	8.6 x 6.3 x 8.02 in	>20 LPM	51-533 mmHg	800 or 1200 cc	399.99	800 cc disposable waste canister, 1200 cc reusable canister		http://www.precisionmedical.com/node/1677
Res-Q-Vac	0.5 lbs	4.49 x 7.1 x 2.15 in	20 LPM	>600 mmHg	300 mL	100.00	disposable waste canister		http://www.rmsmedicalproducts.com/products/medical-suction/res-q-vac/
Roscoe Medical Heavy-Duty Aspirator Suction Machine	5.7 lbs	14.3 x 6.9 x 8.3 in	28 LPM	550 mmHg	1000 cc	352.25	disposable waste canister		https://www.roscoemedical.com/wps/portal/c/products/!ut/p/a1/hc6xDolwEAbgZ2Fg5a4aibp11Chg1EnoYsDUgiktKRVe32pcTBRv-y_fnztgkANT5dCi0jZaIfKZWxiOstVxk8YE48NuhtskjkJCU4J7dKBwAH8MxX_9E7BJguQNJk4kwITU1evdgppqvhTADL9yw01wN25dW9v1ax99HMcxEFoLyYOLbn38Vql1byH_INC1Od4Wcsio5z0AV0mA6g!!/dl5/d5/L2dBISevZ0FBI S9nQSEh/?itemNumber=50004#.W/XaUFIjytEY
SAM E.P.S Portable Suction Unit	10.4 lbs	13.7 x 13 x 6.65 in	32 LPM	0 to 600 mmHg	1000 cc	1,010.00	autoclavable or disposable waste canister	can rotate collection canister up to 90 degrees for uneven terrain	http://www.mgeworldwide.com/Medical/SAMEps.htm
SSCOR QUICKDRAW Alkaline Powered Portable Suction, Olive Drab	2.6 lbs	10.5 x 4.5 x 4.35 in	>30 LPM	80 to 500 mmHg	300 cc/mL	679.00	disposable tubing and suction tip	designend specifically for military field use	http://www.sscor.com/quickdraw_od_portable_suction.html
SSCOR VX-2	8.6 lbs	17 x 9 x 5.25 in	>30 LPM	50 to 525 mmHg	1200 cc/ml	1,175.00	disposable tubing and suction tip	compliant with SAE J3043 standards	http://www.sscor.com/S-SCORT_VX2_specs.html
S-SCORT 9 Suction	8 lbs	9.5 x 7 x 14 in	>30 LPM	120 or 525 mmHg	1200 cc/mL	829.00	disposable tubing and suction tip		http://www.sscor.com/S-SCORT_9_suction_unit.html
S-SCORT II Portable Suction Unit	10 lbs	7 x 7 x 14 in	>30 LPM	120 or 525 mmHg	1200 cc/mL	749.95	disposable tubing and suction tip		http://www.sscor.com/S-SCORT_II_specs.html
S-SCORT III Portable Suction Unit	7 lbs	8 x 7 x 11 in	>30 LPM	120 or 525 mmHg	1200 cc/mL	607.00	disposable tubing and suction tip		http://www.sscor.com/S-SCORT_III_suction_unit.html
S-SCORT Ten	10 lbs	9.5 x 7 x 14 in	>30 LPM	120 or 525 mmHg	1200 cc/mL	1,143.00	disposable tubing and suction tip		http://www.sscor.com/S-SCORT_10_specs.html
Vacu-Aide Portable Compact Suction Unit	3.37 lbs	7.25 x 7.25 x 6.75 in	27 LPM	50-500 mmHg	725 ml	540.00	reusable, autoclave	meets ISO 10079-1:1999 standards	http://www.devilbisshealthcare.com/files/LT-2016_RevF_Vacu-Aide_Compact_FINAL_100114_Web.pdf

Appendix E – Web Links for Images

1. Aeros Tote-L-Vac Suction Unit
https://d2ch1jyy91788s.cloudfront.net/buyemp/images/product/Tote-L-Vac-Suction-Unit-18117903-400_300.png
2. Ambu Res-Cue Manual Suction Pump
<https://d1xxg88b45bl3b.cloudfront.net/Files/Billeder/Product%20Images/RescuePumpLarge.jpg>
3. Curaplex Manual Suction Unit
<http://d1xwdusrophmb1.cloudfront.net/btm/265/10369.jpg>
4. DeVilbiss 7305D Series Homecare Suction Unit
<http://www.devilbisshealthcare.com/images/products/homecare-suction1.jpg>
5. Drive Medical VacuMax Suction Machine with Rechargeable Battery
<https://smhttp-ssl-51929.nexcesscdn.net/media/extendware/ewimageopt/media/inline/15/b/vacumax-suction-machine-with-rechargeable-battery-efd.jpg>
6. EM Innovations Suction Easy Pump
<http://d1xwdusrophmb1.cloudfront.net/btm/265/590412.jpg>
7. Emergency Aspirator from Vitalograph
<https://vitalograph.com/imageLibrary.axd?2827?>
8. Eurovac AC Suction Unit
<http://www.narang.com/suction-machines-units/portable-suction-units/images/suction-unit-eurovac-su03a.jpg>
9. EuroLite Suction Device
<https://www.hospytek.com/images/phpThumb.php?src=1919.jpg>
10. Gomco OptiVac AC/DC Portable Aspirator Model G180
https://cdn2.bigcommerce.com/server3500/55fb4/products/17722/images/15004/url_97343.1365872019.1280.1280.jpg?c=2
11. INSTAD Suction Pump
<http://www.narang.com/suction-machines-units/portable-suction-units/images/suction-unit-instad-ac-su47c.jpg>

12. John Bunn Vacutec 800 EV2 Portable Aspirator Suction Unit
https://www.ventureresp.com/productcart/pc/catalog/jb0112-016copy_263_general.jpg
13. Laerdal Compact Suction Unit LCSU 4 (300 ml) RTCA Certified
https://ds5cvxtqu2rt0.cloudfront.net/media/catalog/product/cache/1/image/265x/9df78eab33525d08d6e5fb8d27136e95/5/7/57931_w.jpg
14. Laerdal Suction Unit
https://cdn0.laerdal.com/cdn-4aeced/globalassets/images--blocks/products/therapy-products/lisu/_bro0184.jpg?w=705&h=396&mode=crop
15. Laerdal V-Vac Starter Kit
<http://www.laerdal.com/images/S/ACYITLZX.jpg>
16. LSP Advantage Emergency Portable Suction Unit
<https://images.mooremedical.com/450x450/74031.jpg>
17. Medela Basic Aspirator
https://cdn.shopify.com/s/files/1/1046/1086/products/medela-basic-aspirator_grande.jpg?v=1485538643
18. Medela Dominant Flex Aspirator
https://cdn.shopify.com/s/files/1/1046/1086/products/medela-dominant-flex-aspirator_grande.jpg?v=1478027543
19. Medline Vac-Assist Portable Aspirator Suction Machine
https://www.medline.com/media/catalog/CA05/CA05_09/CA05_09_02/PF01963/PF01963_PRI03.JPG
20. MedSource Manual Suction Pump
<https://smhttp-ssl-51929.nexcesscdn.net/media/extendware/ewimageopt/media/inline/c6/a/manual-suction-pump-15c.jpg>
21. Morgan Suction Pump
<http://morgansuctionpump.com/wp-content/uploads/2014/12/morgan-pump-new-web-300x197.jpg>
22. North American Rescue (NAR) Tactical Suction Device
https://www.narescue.com/media/catalog/product/cache/1/image/1200x1200/9df78eab33525d08d6e5fb8d27136e95/1/0/10-0018_a_1.jpg

23. Portable Vacuum Absorb Pump Phlegm Suction Unit Suction Machine SXT-5A
<https://i.ebayimg.com/images/g/rmUAAOSw1vIUwNDx/s-l300.jpg>
24. Precision Medical PM66AC EasyGoVac Portable Aspirator Suction Machine
<http://www.precisionmedical.com/sites/www.precisionmedical.com/files/images/PM66/pm66lir.left.png>
25. Res-Q-Vac
<https://www.quadmed.com/prodimage/ProductImage/800/ea0779a4-8f20-452a-b896-f2bd505a2557.jpg>
26. Roscoe Medical Heavy-Duty Aspirator Suction Machine
https://www.rehabmart.com/include-mt/img-resize.asp?path=/imagesfromrd/ros-cf608.jpg&newwidth=650&product_name=Roscoe%20Medical%20Heavy-Duty%20Aspirator%20Suction%20Machine
27. SAM E.P.S. Portable Suction Unit
<http://www.mgeworldwide.com/Medical/Pictures/SAM%20eps%20outside%20emergency%20portable%20suction.jpg>
28. SSCOR QUICKDRAW Alkaline Powered Portable Suction, Olive Drab
<http://www.sscor.com/images/Q8010-Quickdraw-OliveDrab-Black-Cap-400px.jpg>
29. SSCOR VX-2
<http://www.sscor.com/images/VX-2-7700-400px.jpg>
30. S-SCORT 9 Suction
<http://www.sscor.com/images/NINE-7855-400px-white.jpg>
31. S-SCORT II Portable Suction Unit
<http://www.sscor.com/images/II-7792-400px.jpg>
32. S-SCORT III Portable Suction Unit
<http://www.sscor.com/images/III-7824-white-400px.jpg>
33. S-SCORT Ten
<http://www.sscor.com/images/TEN-main-7856-400px.jpg>
34. Vacu-Aide Portable Compact Suction Unit
<http://www.devilbisshealthcare.com/images/products/vacuaide1.jpg>

References

1. Hodgetts, T., Mahoney, P., Evans, G. & Russell, R. Battlefield advanced trauma life support. *JR Army Med Corps* **152**, 1-3 (2006).
2. Costello, M. F. Design, Fabrication, and Testing of a Portable Suction Pump. (Oregon State Univ Corvallis, 2000).
3. Rossi, R., Jäger, G., Ahnefeld, F. & Pfenninger, E. Efficiency of suction pumps for the emergency medicine setting. *Archives of emergency medicine* **9**, 44 (1992).
4. Kinzle, R. *Development of a Field Packable Medical Suction Device* (Army Institute of Surgical Research, MilTech, 2011).